Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs
by Center for Chemical Process Safety

APPENDIX

B

EFFECTS OF EXPLOSIONS ON STRUCTURES

Acquisition of practical knowledge in the field of explosion-induced structural damage is still heavily dependent upon empirical data. Such data, however, usually give information only about those overpressure levels which relate to certain degrees of damage. Other parameters, such as duration, impulse, and shape of the blast wave are not taken into account. Tables containing such information are frequently published. The best known are contained in Glasstone (1966, 1977), a frequently cited reference.

The earliest tables were compiled from data collected from nuclear weapon tests, in which very high yield devices produced sharp-peaked shock waves with long durations for the positive phase. However, these data are used for other types of blast waves as well. Caution should be exercised in application of these simple criteria to buildings or structures, especially for vapor cloud explosions, which can produce blast waves with totally different shapes. Application of criteria from nuclear tests can, in many cases, result in overestimation of structural damage.

Table B-1 (Stephens 1970) is useful in obtaining a quick overview of damage. It describes four damage level zones. A building is totally destroyed (zone A) if it is damaged beyond economical repair. Severe damage (zone B) suggests partial collapse and/or failure of some bearing members. A building in zone C (moderate damage) is still usable, but structural repairs are required. Light damage (zone D) consists of shattered window panes, light cracks in walls, and damage to wall panels and roofs. More detailed information is given in Table B-2, which is based on Glasstone (1977).

Information of the influence of duration on the level of damage can be found in Figure B-1, which was composed by Baker (1983) based on data from Jarret (1968). Jarret's data originated from descriptions of damage to brick houses in London from World War II bomb attacks. These data permitted the development of a relationship among damage, distance, and type of bomb, and thus permitted calculation of explosion yields. Baker (1983) converted this relationship into a pressure-impulse diagram containing iso-damage curves (Figure B-1). The curves in this figure represent the threshold of side-on blast-wave parameters that produce a certain level of damage to brick dwellings.

The curves in Figure B-1 represent primarily the transient nature of blast waves. They do not represent the interaction effects of blast waves and structures, such as multiple reflections and shielding due to the presence of other structures.

TABLE B-2. Damage Produced by Blast

Side-on overpressure (kPa)	*Description of Damage*
0.15	Annoying noise
0.2	Occasional breaking of large window panes already under strain
0.3	Loud noise; sonic boom glass failure
0.7	Breakage of small windows under strain
1	Threshold for glass breakage
2	"Safe distance," probability of 0.95 of no serious damage beyond this value; some damage to house ceilings; 10% window glass broken.
3	Limited minor structural damage
3.5–7	Large and small windows usually shattered; occasional damage to window frames
5	Minor damage to house structures
8	Partial demolition of houses, made uninhabitable
7–15	Corrugated asbestos shattered. Corrugated steel or aluminum panels fastenings fail, followed by buckling; wood panel (standard housing) fastenings fail; panels blown in
10	Steel frame of clad building slightly distorted
15	Partial collapse of walls and roofs of houses
15–20	Concrete or cinderblock walls, not reinforced, shattered
18	Lower limit of serious structural damage 50% destruction of brickwork of houses
20	Heavy machines in industrial buildings suffered little damage; steel frame building distorted and pulled away from foundations
20–28	Frameless, self-framing steel panel building demolished; rupture of oil storage tanks
30	Cladding of light industrial buildings ruptured
35	Wooden utility poles snapped; tall hydraulic press in building slightly damaged
35–50	Nearly complete destruction of houses
50	Loaded tank cars overturned
50–55	Unreinforced brick panels, 25–35 cm thick, fail by shearing or flexure
60	Loaded train boxcars completely demolished
70	Probable total destruction of buildings; heavy machine tools moved and badly damaged

TABLE B-1. Damage Levels

Zone	*Damage Level*	*Side-on overpressure (kPa)*
A	Total destruction	>83
B	Severe damage	>35
C	Moderate damage	>17
D	Light damage	>3.5

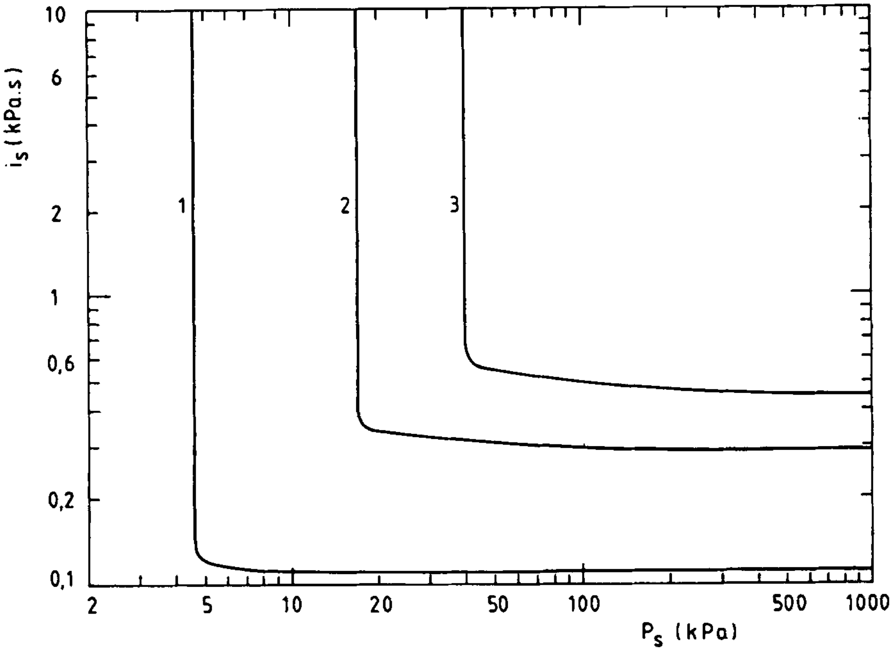

Figure B-1. Pressure impulse diagrams for damage to brick houses. ***Line 1:*** **Threshold for light damage.** ***Line 2:*** **Threshold or moderate damage: partial collapse of roof; some bearing wall failures.** ***Line 3:*** **Threshold for severe damage: 50 to 75 percent of bearing wall destruction. P_s: side-on overpressure. i_s: side-on impulse (Baker et al. 1983).**

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